GLOBAL OBSERVATION RESEARCH INITIATIVE IN ALPINE ENVIRONMENTS: ESTABLISHING GLORIA LONG-TERM ALPINE MONITORING IN THE LEMHI MOUNTAINS, IDAHO




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SUMMARY
The alpine zone represents an ecosystem at a climate extreme; one that is very temperature dependent and predicted to be a sensitive indicator to climatic changes. GLORIA (Global Observation Research Initiative in Alpine Environments) is a program to establish and maintain a worldwide, long-term monitoring network for comparative study of climate change impacts on mountain vegetation and its biodiversity. The GLORIA monitoring program aims to document vegetation changes over time in alpine environments using plots established on a set of summits that represent a low to high alpine elevational gradient within a target region. In 2018 and 2019, we established the first GLORIA target region in Idaho, in the Lemhi Mountains. Plot establishment and baseline sampling was completed on four summits – Bruce Canyon Peak, Spring Mountain, Sheep Mountain South, and Sheep Mountain, all located south of the historic mining town of Gilmore. GLORIA summits ranged from 3066 m (10050 ft) for Bruce Canyon Peak, to 3312 m (10865 ft) elevation at Sheep Mountain, a gradient extending from a short distance upslope of the treeline ecotone to the regional upper alpine.

Sampling recorded a total of 84 vascular plant species at the 4 GLORIA summits, including 1 tree, 2 shrub, 13 graminoid, and 68 forb species. Spring Mountain had the most floristic diversity with 65 species, and Sheep Mountain the least with 34 species. Overall, relative abundance of vascular plant cover decreased as summit elevation increased. Vegetation cover on each summit was dominated by graminoid species, specifically *Carex elynoides* at Bruce Canyon Peak, *Calamagrostis purpurascens* with lesser amounts of *Carex elynoides* and *Carex rupestris* at Spring Mountain, and *Carex rupestris* at Sheep Mountain South and Sheep Mountain. Forb diversity was relatively high at each summit, but with only a few species contributing more than trace cover. Spring Mountain and Sheep Mountain South had a few *Taraxacum officinale* plants, the only non-native plant species recorded at a GLORIA site. Two species of conservation concern in Idaho were recorded at the GLORIA summits. *Cymopterus douglassii* was one of the more widespread and common forbs at Sheep Mountain South and Sheep Mountain, but absent from the other two summits. *Pinus albicaulis* was limited to a solitary small individual at Spring Mountain, a few scattered small individuals at Sheep Mountain South, and a few alive and dead seedlings on Sheep Mountain. GLORIA has evolved to include several optional data collection activities directly related to, but usually not confined to the summit sites. In this context, Idaho GLORIA established and sampled downslope survey transects for *Pinus albicaulis* in 2019. In addition, an alpine bee community inventory initiated in 2018 was continued in 2019.

High elevation ecosystems in Idaho are important for watershed, wildlife, biodiversity, aesthetic, and other values. GLORIA monitoring is relevant for Idaho because alpine habitat is relatively limited in distribution and extent in the state. Loss/contraction of alpine habitat due to climatic changes has the potential to seriously impact Idaho's high elevation biota. GLORIA monitoring can provide land managers and others interested in high elevation ecosystems a better understanding of the relationships linking climate change and alpine biodiversity. It provides a program to help document, monitor, and assess possible long-term shifts and vulnerabilities to alpine vegetation in the Lemhi and other nearby mountain ranges. This information has the potential to inform and help guide future conservation activities benefiting Idaho's iconic alpine landscapes.

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INTRODUCTION

The alpine zone represents an ecosystem at a climate extreme; one that is very temperature dependent and predicted to be a sensitive indicator to climatic changes (Pauli et al. 2015 and references cited within). GLORIA (Global Observation Research Initiative in Alpine Environments) is a program to establish and maintain a worldwide, long-term monitoring network for comparative study of climate change impacts on mountain vegetation and its biodiversity (Pauli et al. 2015). The GLORIA monitoring program aims to document vegetation changes over time in alpine environments using plots established on a set of summits that represent a low to high alpine elevational gradient within a target region. Standardized sampling protocols collect data in an arrangement of nested plots positioned within the top 10 vertical meters of the summit. Monitoring focuses on changes in plant species richness (number of species), plant species composition (species loss or gain), plant species abundance (percent cover and frequency), soil temperature, and snow cover (indirectly through soil temperature measurements).

The first GLORIA sites were established in Europe in 2001. The program soon expanded to all other continents except Antarctica and now includes target regions in at least 40 countries (Global Observation Research Initiative in Alpine Environments 2001 - 2018). In the United States, GLORIA sites have been established in California, Montana, Wyoming, Colorado, Nevada, and Oregon. We initiated the first GLORIA target region in Idaho in 2018, in the Lemhi Mountains, in the east-central part of the state. The four GLORIA summits are all located within an approximately 4.5 km (2.8 mi) long section of the central part of the Lemhi Mountains, south of the historic mining town of Gilmore (Figure 1). The summits are referred to as Bruce Canyon Peak, Spring Mountain, Sheep Mountain South, and Sheep Mountain (Table 1). Plot establishment and baseline sampling were completed on three summits in 2018, and on a fourth summit in 2019. This report summarizes information about each of the Idaho GLORIA summits and the complete four-summit dataset. It restates, but updates, much of the information contained in an earlier, preliminary report that synthesized information collected during the 2018 Idaho GLORIA project (Mancuso and Lehman 2019).

Table 1. GLORIA summits in the Lemhi Mountains.

GLORIA Summit (summit code)	Date established	Elevation m (ft)	Land ownership
Bruce Canyon Peak (BRU)	16 Jul 2018	3066 (10050)	Salmon-Challis NF
Spring Mountain (SPR)	18 Jul 2018	3103 (10180)	Caribou-Targhee NF
Sheep Mountain (SHA)	19 Jul 2018	3312 (10865)	Salmon-Challis NF
Sheep Mountain South (SHB)	24 Jul 2019	3164 (10380)	Salmon-Challis NF

PROJECT AREA

The Lemhi Mountains are located in east-central Idaho and form one of the longest and highest mountain ranges in the state. They rise above the Snake River Plain and extend northward for approximately 160 km (100 mi), varying from approximately 16 to 24 km (10 to 15 mi) wide along this length. Elevations range up to 3718 m (12,197 ft) at the summit of Diamond Peak, with four other named peaks rising above 3353 m (11,000 ft). Most high peaks repeatedly supported large glaciers in the past (Ruppel and Lopez 1988). Alpine habitats are restricted to a narrow band along the crest of the range above approximately 3050 m (10,000 ft) elevation.

The Lemhi Mountains are a fault block range that lie within the Cordilleran fold and thrust belt at the northern end of the Basin and Range geologic province (Link and Janecke 1999). Different geologies dominate the northern and southern portions of the Lemhi Range. In general, Proterozoic-age quartzites belonging to the Yellowjacket, Swauger, Gunsight, and related Formations of Belt Supergroup rocks dominate the northern half; compared to Paleozoic sedimentary rocks dominating the southern half of the Lemhi Range (Ruppel and Lopez 1988). The GLORIA summits are located

near the center of the range, at the northern end of the section dominated by Paleozoic rocks. Proterozoic strata form most of the geology beginning just a few miles further north (Rember and Bennett 1979, Ruppel and Lopez 1988). The nearest town to this portion of the Lemhi Range is Leadore in the upper Lemhi River Valley, located approximately 35 km (22 mi) to the north. GLORIA summits are located on lands administered by either the Salmon-Challis NF or the Caribou-Targhee NF (Table 1).

Geology at the four GLORIA summits is mapped as Three Forks and Jefferson Formations, and Laketown Dolomite (Ruppel and Lopez 1988). Silurian age Laketown Dolomite rocks consists of light-gray weathering, finely to medium-crystalline dolomite characterized by a sparkling appearance in freshly broken surfaces. It is exposed in many places along the eastern flank of the central Lemhi Mountains. The Three Forks and Jefferson Formations are both of Devonian age, the former consisting of yellowish and pinkish to light-gray, very finely crystalline limestone, silty limestone, and calcareous siltstone; the latter of brownish to light or dark grayish dolomitic sandstone or other dolomitic and non-dolomitic rocks. In the Lemhi Range, both the Three Forks and Jefferson Formations are best exposed in the Gilmore area. Surface rocks at each of four GLORIA summits appeared to be the Laketown Dolomite component of this geologic unit.

Climate in the east-central Idaho mountains has both coastal and continental influences giving rise to cold, wet winters, and warm, dry summers (Ross and Savage 1967). Prevailing winds are from the west. January is the coldest month and July the warmest. Annual precipitation at the GLORIA summits is probably similar to the 853 mm (34 in) reported for Meadow Lake, a high subalpine site located a few miles north of Sheep Mountain (cited in Urbanczyk and Henderson 1994). The majority of moisture falls during the winter months as snow. Summers are dry, with precipitation largely limited to occasional rain showers. Ecological classification places the Lemhi Mountains within the Beaverhead Mountains Section of the Middle Rocky Mountains Province (McNab and Avers 1994).

Alpine soils in the central Lemhi Mountains predominately formed as colluvium and slope alluvium from limestone and dolomite. Landforms include cirque headwalls, ridges, gentle to steep mountain slopes, and saddles. Rubble land and rock outcrops tend to cover a large percentage of areas near cirque headwalls, and lesser amounts on other landforms. Soils generally classify to Inceptisol and Mollisol orders of soil taxonomy. Textures range from silt loam to sandy loams, with 35 to 85 percent gravels and cobbles. Mineralogy of the soils is dominated by the carbonatic limestone. Depth to bedrock varies from 50 cm (20 in) on summits and shoulders to greater than 150 cm (59 in) on mountain slopes, swales, and saddles (Carla Rebernak, MLRA Soil Survey Leader, Natural Resources Conservation Service, 2018, pers. comm.).

The Spring Mountain and Bruce Canyon Peak GLORIA summit areas are mapped as the Alpine Graminoid Fritz Ecological Type (Map Unit TEU 8), a classification unit occurring on windswept mountain summits in the alpine zone that supports low-growing alpine graminoid vegetation on Fritz series soils (U.S. Forest Service 1997). This ecological unit has a cryic soil temperature regime and xeric soil moisture regime. Winds that remove a portion of the snowpack, desiccating winds, and minimal summer rains contribute to the prevalence of dry soil conditions in late summer and autumn. A part of the Spring Mountain GLORIA summit also overlaps the Low Alpine Forb Cryochrepts, loamy-skeletal Ecological Type (Map Unit 1280), a classification unit that supports low-growing alpine forb communities (U.S. Forest Service 1999). This ecological unit has a cryic soil temperature regime and udic soil moisture regime. The Sheep Mountain South and Sheep Mountain GLORIA summits are mapped as the Low Alpine Forb Cryochrepts, loamy-skeletal Ecological Type (Map Unit TEU 9) that has characteristics similar to Map Unit 1280 (U.S. Forest Service 1997).

Land use in the central Lemhi Mountains includes historical mining, livestock grazing, and recreation. Prospecting for mineral deposits in the area began in the 1860s, although the earliest noteworthy discoveries were not made until 1880 (Ruppel and Lopez 1988). Mining operations fizzled out in the

area in the late 1880s when deposits at the larger mines were exhausted. However, mining activity resumed in the early 1900s with the discovery of new deposits of lead, silver, and other precious metals in the Spring Mountain and Texas Mining Districts. One result of this renewal was establishment of the town of Gilmore in 1903. Operations declined after about 1925 and most mining in the area ended a few years later. The four GLORIA summits occur within the boundaries of the Spring Mountain and Texas Mining Districts (Ruppel and Lopez 1988). None of the GLORIA summits have evidence of past or recent mining disturbance, although remnants of small mines or prospects occur within approximately 0.8 km (0.5 mi) of each site. The network of dirt roads in the area was originally constructed to access the mines and prospects. Three of the four GLORIA summits are located within the boundaries of the Sheep Mountain Research Natural Area (RNA).

Seasonal livestock grazing occurs at lower elevations, but has been historically insignificant in the vicinity of the GLORIA summits due to the lack of perennial surface water in the alpine zone. Although most alpine areas in the central Lemhi Mountains are not closed to livestock they receive little if any use. Most current activity in the central Lemhi Range centers on recreation, and at high elevations generally involves the use of motorcycles and all-terrain or other high-clearance 4-wheel drive vehicles. Steep, narrow, rough roads up the Squaw Creek and Spring Mountain Canyon drainages cross the Lemhi crest and are popular rides that provide access to a section of alpine habitat in the Spring Mountain-Big Windy Peak area. The GLORIA summits lie approximately 0.3 to 2.2 km (0.2 to 1.4 mi) from points along this road system. Maintained hiking trails do not occur near the GLORIA summits, but the road network is used by a small number of hikers and climbers to access high ridges and peaks via cross-country travel.

GLORIA SUMMITS

A GLORIA target region consists of a set of four (minimum three) summits that represent an elevation gradient from the upper treeline ecotone upslope to the uppermost alpine vegetation zone (Pauli et al. 2015). The target region is the mountain range or area in which the selected summits are located. Selecting a set of suitable summits is the first requirement when establishing a new GLORIA target region. Selected summits need to meet a set of six standard criteria (Pauli et al. 2015):

(1) Summits need to lie outside areas of active volcanism.

(2) Summits should be exposed to the same local climate. Ideally, climatic differences between summits are caused only by their different altitudinal positions.

(3) Summits should be composed of similar bedrock. A mix of contrasting bedrock types should be avoided to alleviate differences in species richness and composition that could be substrate-related.

(4) Summits should not be in areas obviously altered or affected by human interference or land uses such as mining, livestock grazing, or excessive recreation.

(5) Summits should be of “moderate” geomorphologic shape - very steep, as well as flat plateau-like summits are unsuitable for the application of GLORIA protocols. Ideally, summits should have a more or less conical shape that can accommodate plots on all sides (north, south, east, west aspects). The terrain needs to be safe to access and sample without the use of technical climbing equipment.

(6) Prevalent vegetation on the chosen summits should be representative for the typical species occurring in the respective elevation belt. Summits dominated by solid rock, unstable scree fields, or large boulder fields, should be avoided.

Reconnaissance trips in 2017 and 2018 investigated an approximately 11-mile section of the Lemhi Range for summits potentially suitable for GLORIA, from Portland Mountain southward to Trail Peak. This reconnaissance formed the basis for selecting the four summits used to represent the GLORIA Lemhi Mountains target region (Figure 2). All four summits are positioned along the crest of the Lemhi Range, a divide separating the Little Lost River drainage to the west and Birch Creek Valley to the east. Selected summits encompass the low to high elevational alpine gradient of the Lemhi Range and also meet the climatic and bedrock consistency, summit shape, researcher safety, human-related disturbances/impacts, and representative vegetation patterns criteria required for GLORIA. We also considered accessibility when selecting the GLORIA summits, choosing summits requiring less than a

2-hour hike from the nearest road. Having relatively accessible summits facilitated logistics in 2018 and 2019 and will help future resampling efforts be carried out on a regular schedule.

GLORIA summits for the Lemhi Mountains target region

Bruce Canyon Peak (3066 m; 10050 ft): This is an unnamed minor summit that we named Bruce Canyon Peak for its location at the head of the Bruce Canyon drainage. It is accessed via an approximately 1.1 km (0.7 mi) walk north from the saddle at the upper end of the Squaw Creek Road, a point along the Lemhi crest at the head of Quartzite Canyon. Bruce Canyon Peak represents the lowest elevation alpine site included in the set of GLORIA summits. The High Summit Point (HSP) is located towards the northern end of a gentle north-south-trending ridgecrest. The upslope edge of the closest *Pinus albicaulis* (whitebark pine) woodland is located approximately 165 m (540 ft) southeast of the high point, at approximately the 3018 m (9900 ft) contour. Bruce Canyon Peak is located within the Sheep Mountain RNA.

Spring Mountain (3103 m; 10180 ft): This summit is positioned near the northern terminus of the Spring Mountain block and accessed via an approximately 0.5 km (0.3 mi) walk north from the road that reaches the Lemhi crest at the head of Spring Mountain Canyon. The HSP is located at the north end of the gentle north-south-trending ridgecrest that characterizes the northern half of the mountain. Widely scattered, stray whitebark pine occur within approximately 40 m (130 ft) southeast of the HSP at approximately 3088 m (10130 ft) elevation. The upslope edge of the nearest whitebark pine woodland is located approximately 100 m (330 ft) further downslope at approximately the 3030 m (9940 ft) contour. Spring Mountain is located south of the Sheep Mountain RNA.

Sheep Mountain South (3161 m; 10370 ft): This summit has no official name. It is a knob-like high point located along the Lemhi Range crest approximately 1.3 km (0.8 mile) south of Sheep Mountain. Access is via an approximately 1 km (0.6 mi) walk northward along the crestline from Bruce Canyon Peak. The immediate summit zone is nearly flat with gentle topography on north, south, and west aspects, countered by abruptly steep northeast and east-facing slopes. This terrain limited safe sampling to the uppermost 5 meters for the east aspect portion of the summit. A few small (<0.5 m tall) scattered whitebark pine occurred within and near the summit zone. A larger individual (1.5 m tall) was positioned approximately 60 m (197 ft) downslope of the HSP on the west aspect. The nearest stand of contiguous trees extended up to approximately the 3048 m (10000 ft) contour on the west-facing slope. Sheep Mountain South is located within the Sheep Mountain RNA

Sheep Mountain (3312 m; 10865 ft): Sheep Mountain is one of the highest peaks in the central Lemhi Range and the highest elevation GLORIA summit. It is accessed by walking approximately 2.4 km (1.5 mi) further north along the Lemhi Range crest from Bruce Canyon Peak. The summit zone consists of a very steep (near vertical) north face, a nearly flat easterly aspect that eventually steepens, and gentle to moderately sloped southerly and westerly aspects. This topography precludes GLORIA sampling on the precipitous north aspect. Individual whitebark pine ascend to approximately 3140 m (10300 ft) elevation on the steep west flank of Sheep Mountain, but woodland formation is generally below the 3048 m (10000 ft) contour. The Sheep Mountain RNA includes its namesake.

METHODS

GLORIA uses a standardized monitoring protocol with sampling and data collection taking place in a series of plots located within the top 10 vertical meters below, and 100 horizontal meters distance from the HSP (Figure 3). GLORIA data collection includes a set of four mandatory sampling protocols and several optional, supplemental protocols. Required sampling includes:

1. The collection of percent cover data and frequency counts for all vascular plant species and ground surface attributes using a 1m x 1m quadrat positioned within a 3m x 3m sample grid. The grids are positioned 5 vertical meters from the HSP in each cardinal direction (N, E, S, W). Four 1m x 1m

quadrats are sampled within each grid. Thus, data are collected in a total of 16 quadrats, 4 in each of the cardinal directions.

2. The division of each summit into 8 Summit Area Sections (SAS); 4 sections in the upper 5 vertical meters from the HSP, and 4 sections in the lower 5 vertical meters. An inventory of all vascular plant species and their assignment to 1 of 5 abundance categories is made within each SAS. Percent cover for ground surface attributes is also estimated for each SAS. The 5 abundance categories are defined as:
Very rare – one or a few small individuals.
Rare – some individuals at several locations that can hardly be overlooked in careful observation.
Scattered – widespread although not necessarily evenly dispersed; can hardly be overlooked, but presence not obvious at first glance.
Common – occurring frequently and widespread; presence obvious at first glance, although covering <50% of the SAS area.
Dominant – very abundant, making up a high proportion of the phytomass; covering >50% of the SAS area.

3. The burial of 1 soil temperature data logger 10 cm deep within each 3m x 3m sample grid. This results in the placement of 4 data loggers for each summit. Data loggers are programed to take a temperature reading once an hour, all day, every day (battery life is 4 - 5 years). In general, this design is meant to provide information on snowpack duration and climatic conditions for the summit's four cardinal directions (Pauli et al. 2015). Measured soil temperature series enable calculations of temperature indices such as mean, minima, maxima and temperature sums, annually and/or for certain periods. Growing season length can also be calculated by determining dates of snow accumulation and snow melt (Pauli et al. 2015).

4. The taking of a large set of photographs meant to aid in relocating the various plot markers during future revisits, provide visual documentation of the vegetation and terrain, and be useful for photo monitoring purposes.

The GLORIA Manual (Pauli et al. 2015) also includes several optional, supplemental data collection methods. Following the lead of the Great Basin GLORIA program, we chose to incorporate the 10m x 10m Square Plot supplemental method into the Idaho GLORIA program. One strength of this method is to provide a larger sampling area than the 3m x 3m grids to compare diversity patterns between the four cardinal directions (Pauli et al. 2015). It also provides more quantitative data compared to the SAS abundance categories. Line-pointing data collected with this method can be used to calculate percent cover values for individual plant species as well as their total top cover value.

In addition to the standard and supplemental monitoring methods, GLORIA has evolved to include other optional data collection activities directly related to, but usually not confined to the summit sites (Pauli et al. 2015). GLORIA refers to these activities as 'extra approaches'. Versions of two of these extra approaches were implemented for the Lemhi Mountain target area. The first involved establishing downslope monitoring transects in 2019 for whitebark pine in association with the Bruce Canyon Peak and Spring Mountain GLORIA sites. The second extra approach involved sampling bee communities near the GLORIA summits in 2018 and 2019. This was done by net-collecting bees at multiple plant species, trying to represent the prevalent bee species visiting each of the flowering species.

The GLORIA 'Downslope Survey' protocol samples all plant species on a series of belt transects (1 m x 100 m) laid out along the contour every 25 m downslope from the summit, and centered on the cardinal direction lines. We modified the protocol to sample only whitebark pine. Because the pine occurred at relatively low densities, we increased the width of the belt transect to 5 m, and counted the number of trees, rather than estimating their cover. We also collected data on additional

parameters, including tree height and diameter, presence of male and female cones, evidence of white pine blister rust (*Cronartium ribicola*), evidence of mountain pine beetles (*Dendroctonus ponderosae*), and whether the tree was alive or dead.

Whitebark pine occurred in sufficient quantities for monitoring only on the east cardinal line of Spring Mountain (beginning at 25 m downslope from the summit), and the south cardinal line of Bruce Canyon Peak (beginning at 150 m downslope from the summit). Five belt transects were established at each site. The 100-m transects were centered on the cardinal direction line and followed the contour on both peaks. Once established using two 50-m tapes, the transects were photographed and received GPS coordinates. Sampling involved one or two observers walking the length of the tape and recording whitebark pine within 2.5 m on either side of the tape. The whitebark pine downslope monitoring effort was led by Lynn Kinter. Results from the downslope survey are not included in this report. Instead, results and other details will be provided in a separate report.

Data collection methods for all protocols are described in detail in the GLORIA Field Manual (Pauli et al. 2015) and not repeated here. Plot establishment details are also outlined in the GLORIA Field Manual (Pauli et al. 2015). The following section provides a general overview of how we established the Idaho GLORIA plots. All azimuths were determined using a compass set to 12° east declination.

Plot establishment

High Summit Point: The HSP typically marks the highest point on the summit and is the starting point for all measurements used to establish the GLORIA site. An “X” etched into a piece of solid rock marks the HSP at each summit.

Establishing the cardinal direction lines: Our first measurements were to locate points 5 vertical meters and 10 vertical meters below the HSP in each of the four cardinal directions (geographic N, E, S, W). We used a measuring rod expandable to a height of 8 m and a clinometer to determine these points. We set the rod to a height of 6.64 m (corresponding to the needed 5 m elevation drop + 1.64 m, the eye-level standing height of the person reading the clinometer). Standing at the HSP, the person with the clinometer determined the 5 m drop in vertical elevation for each of the cardinal directions by guiding the person with the rod to the point where the clinometer read 0° (level) when directed at the 6.64 m mark on the measuring rod. A repeat of this procedure determined the 10 vertical meter drop point. The only difference was that the person with the clinometer stood at the newly established 5-m point instead of the HSP. We laid colored string from the HSP to the 5-m and 10-m points for each of the cardinal directions.

Establishing the 3m x 3m grids along the cardinal direction lines: The 5-m point along the cardinal direction line serves as the reference point to establish the 3m x 3m quadrat cluster grids. The grids can be positioned on either the right side or left side of the direction line. We made an arbitrary, left or right side decision at each 5-m cardinal direction point. However, terrain or habitat conditions dictated the choice for us in cases where one side of the line was too steep or erosive to sample safely, or where one side was largely rock with little or no vegetation compared to the other side. In these cases, we chose to sample the less erosion-prone side of the line, or the side with higher vegetation cover.

Delineating the upper and lower Summit Areas and the Summit Area Sections: The summit area is divided into separate upper and lower parts. The upper Summit Area encompasses the upper 5 vertical meters around the summit; the lower Summit Area encompasses the zone 5 to 10 vertical meters below the summit. The upper and lower Summit Areas are then each subdivided into four Summit Area Sections.

Delineating the upper Summit Area - The upper Summit Area can be delineated once all the cardinal direction strings and their associated 3m x 3m grids are in place. The lower right and lower left corner

points of each 3m x 3m grid are used to guide placement of the string line that delineates the upper Summit Area. A string around the summit connects these eight corner points to delimit the downslope perimeter of the upper Summit Area. The corner points are connected around the summit in straight surface lines. Although the upper Summit Area is at the 5 m level at the 3m x 3m grids, it often lies above the 5 m contour line between the grids.

Delineating the lower Summit Area - The previously marked N, E, S, and W 10-m points form the corner points for the lower Summit Area. A string is laid to connect these four corner points, forming a straight line between each corner. This string delineates the downslope perimeter of the lower Summit Area. The lower Summit Area is therefore the area between the strings that delineate the downslope perimeters of the upper and lower Summit Areas.

Delineating the Summit Area Sections – The upper and lower Summit Areas are each subdivided into four Summit Area Sections. This is done by placing a string in a straight line from the HSP to the 10-m lower Summit Area perimeter string in the NE, SE, SW, and NW (intercardinal) directions. This arrangement subdivides the upper and lower Summit Areas into four sections each: NE-SE, SE-SW, SW-NW, and NW-NE.

Establishing the 10m x 10m Square Plots: This is a supplementary method applied within the Summit Area in each of the four cardinal directions. Each of the four plots overlaps into portions of both the Upper and Lower Summit Areas. The lower corner point of the 3m x 3m grid represents the midpoint of the 10m x 10m plot. Measurements from this midpoint are used to fix the upper and lower corner points of the plot. We used 2, pre-measured 20-m lengths of cord to establish the plot perimeter; with each piece of cord covering two of the 10-m sides of the plot. Both cords start from the same point and end at the same point diagonally opposite their start point. A 10-m section of each 20-m cord is pre-marked every meter beginning and ending 0.5 m from the cord ends. A separate 10-m cord marked at 1-m intervals is placed between opposing meter marks on the perimeter cords and used to guide sampling and the collection of line-pointing data in the plot.

Marking summit reference points: We marked important plot reference points with outdoor-rated chrome-color paint sprayed as a circular patch onto a rock positioned at (or in some cases close to if no rock present) the reference point. Painted reference points at each summit included the HSP; all 5-m and 10-m points along the principal cardinal direction lines; all corners for the 3m x 3m grids; all points where the intercardinal lines intersect the 5-m and 10-m Summit Area Sections lines; and at each soil temperate data logger burial location. We also hammered 5-inch aluminum nails into the ground at all 5-m and 10-m points along the principal cardinal direction lines. The HSP was further marker by etching a “X” in exposed bedrock or the protruding part of a partly buried rock at the point.

RESULTS

GLORIA summits

Plot establishment and baseline sampling were completed for three GLORIA summits in July, 2018, and at a fourth summit in July, 2019 (Table 1). GLORIA summits range from 3066 m (10050 ft) to 3312 m (10865 ft) elevation, a gradient extending from a short distance upslope of the treeline ecotone to the regional upper alpine. No peaks in the Lemhi Range or elsewhere in Idaho reach elevations high enough to have a nivial zone. GLORIA summit zone slopes range from <5° to approximately 30°.

Monitoring data were recorded on standardized GLORIA field data sheets, including Forms 0, 1, 2, 3, 4, and 6-S (Appendix 1). Sampling at each summit included: (1) the collection of percent cover and frequency data for all vascular plant species and ground surface attributes recorded in 1m x 1m quadrats within a 3m x 3m sampling grid (Form 2); (2) an inventory of all vascular plant species within each SAS and assigning an associated abundance category (Form 3); and (3) the collection of line-pointing data for all vascular plant species and ground surface attributes recorded in 10m x 10m

square plots (Form 6-S). To collect soil temperature data, HOBO MX Tidbit 400 (manufactured by Onset) data loggers were buried at each summit (Form 4). In addition, an extensive set of photographs taken at each summit helps document the vegetation and other summit and landscape features.

The location of each GLORIA summit has been mapped (Figure 2) and documented with GPS coordinates (Appendix 2). Additional GPS points and notes regarding plot establishment and data collection were taken at each summit to facilitate future resampling efforts (Appendix 2). Monitoring data recorded on field forms (Appendix 1) were converted to spreadsheet format (Appendix 3) to facilitate data compilation, synthesis, and future uploading into the GLORIA database. The Idaho GLORIA photoset consists of >230 photographs that will be uploaded into the GLORIA program database.

Sampling recorded a total of 84 vascular plant species at the four GLORIA summits, including 1 tree, 2 shrub, 13 graminoid, and 68 forb species (Table 2). Spring Mountain had the most floristic diversity with 65 species and Sheep Mountain the lowest diversity with 34 species. Not sampling the north aspect at Sheep Mountain due to its cliff-like topography contributed to the summit's relatively low floristic diversity. Overall, 22 (26%) species were recorded on all 4 summits; 7 (8%) species were recorded on 3 summits; 25 (30%) species were recorded on 2 summits; and 30 (36%) species were limited to a single summit (Table 2). Spring Mountain had 17 unique taxa, compared to 9 for Bruce Canyon Peak, 3 for Sheep Mountain South, and 1 for Sheep Mountain (Table 2). Three plant families, Asteraceae with 20 species (25%), Poaceae with 13 species (15%), and Brassicaceae with 8 species (10%) accounted for half (50%) of the overall recorded plant species richness. Six genera were especially well represented on the GLORIA summits with at least 4 species each, including *Antennaria*, *Arenaria* (*sensu lato* with *Arenaria* and *Minuartia*), *Draba*, *Poa*, and *Townsendia*. Spring Mountain and Sheep Mountain South each had a few *Taraxacum officinale* (common dandelion) plants, the only non-native plant species recorded during GLORIA sampling.

Based on 1m x 1m quadrat sampling, average vascular plant cover ranged from 36% at Bruce Canyon to 25% at Sheep Mountain (Table 3). The 36% average plant cover value at Bruce Canyon Peak is 8 - 11% higher than any of the other three GLORIA summits. Overall, the relative abundance of vascular plant cover decreased as summit elevation increased. Vegetation cover on each summit was dominated by graminoid species, specifically *Carex elynoides* at Bruce Canyon Peak, *Calamagrostis purpurascens* with lesser amounts of *Carex elynoides* and *Carex rupestris* at Spring Mountain, and *Carex rupestris* at Sheep Mountain South and Sheep Mountain (Tables 3 and 4). Contributions from other graminoid species tended to be relatively minor. Forb diversity was relatively high at each summit, but with only a few species contributing >1% cover. Vascular plant cover in relation to slope aspect lacked a consistent pattern. Quadrat sampling recorded the highest plant cover value on the north aspect at Bruce Canyon Peak, the south aspect at Spring Mountain, the west aspect at Sheep Mountain South, and the east aspect at Sheep Mountain (Table 3). In comparison, species richness was highest on the south aspect at Bruce Canyon Peak, Sheep Mountain, and Sheep Mountain South, but on the north aspect for Spring Mountain (Table 5). It was not uncommon for species to show variations in presence-absence and/or abundance between north, south, east, and west aspects.

Sampling 1m x 1m quadrats recorded 58 (69%) of the 84 plant species associated with the four summits (Table 3). The majority (76%) of species always averaged <1% cover across north, south, east, and west aspects of a summit. The 14 (24%) species that averaged >1% cover on at least one summit tended to have cover values of <3%. The only exceptions were *Calamagrostis purpurascens*, *Carex elynoides*, *Carex rupestris*, and *Phlox pulvinata* which averaged ≥5% cover in quadrat sampling on at least one summit. *Carex rupestris* was the only species to average >1% cover in quadrat sampling on all four summits. *Calamagrostis purpurascens*, *Carex elynoides*, *Minuartia obtusiloba* and *Phlox pulvinata* averaged >1% cover on three summits. Tree and shrub species were not recorded in

any 1m x 1m quadrats. Quadrat sampling found scree to be the most common surface feature, averaging >50% cover at each summit (Table 3). Bryophytes and lichens each contributed <2% cover on a summit. Other surface features such as rock, bare ground, and litter each averaged <10% cover on a summit, the only exception being rock at Sheep Mountain South with 11%.

Summit Area Section sampling assigned each plant species encountered to one of five abundance categories - “very rare”, “rare”, “scattered”, “common”, or “dominant”. Species categorized as “very rare” or “rare” were more numerous those categorized as “scattered” or “common” in the majority (66%) of SAS plots (Table 6). Relatively few species were rated “common” in at least half of the SAS plots on a summit (Table 7). *Carex elynoides*, *Carex rupestris*, and *Phlox pulvinata* were the only species rated “common” in a majority of SAS plots at more than one summit. The “dominant” abundance category was not assigned to any species on any summit. Overall, a total of 29 SAS plots were sampled for the four summits. The number of species recorded in each one ranged from 8 to 48, but the majority (72%) had ≥20 species (Table 6). Discounting plant cover, SAS estimates for ground surface attributes showed scree to strongly dominate the ground surface at all summits (Table 8).

Data collection in the 10m x 10m square plots recorded 67 (80%) of the 84 plant species found at the four summits (Table 4). The majority (75%) of species always had <1% cover for the summit when averaged across north, south, east, and west aspects. At Bruce Canyon Peak, the 17% average cover for *Carex elynoides* was at least four times greater compared to any other species. *Phlox pulvinata* averaged 4% cover, the highest value compared to the other five forb species with ≥1% average cover on the summit. At Spring Mountain, *Calamagrostis purpurascens*, *Carex elynoides*, and *Carex rupestris* combined to average 17% cover for the four aspects. In comparison, all other species averaged a combined 15% cover, including 2% cover for *Phlox pulvinata*, the highest value for any forb species. At 29%, *Carex rupestris* had at least 10 times greater cover than any other species at Sheep Mountain South except *Calamagrostis purpurascens* and *Cymopterus douglassii*. With an average cover of 4%, *Cymopterus douglassii* had more than 2 times greater cover than any other forb species on this summit. *Carex rupestris* averaged 12% cover and *Phlox pulvinata* 5% cover for south, east, and west aspects (north not sampled) at Sheep Mountain. All other species combined to average 4% cover. Scree was the most common surface feature attribute in all 10m x 10m square plots, averaging more than twice the total of all other surface types combined (Table 4).

Two plant species of conservation concern were recorded at the GLORIA summits. *Cymopterus douglassii* (Douglass’ wavewing) was one of the more widespread and common species at Sheep Mountain South and Sheep Mountain, but absent from the other two summits. A solitary whitebark pine approximately 0.3 m tall occurred on the eastern upper slope of Spring Mountain, tucked in a small protected alcove beneath a shelf of exposed bedrock. Another solitary small whitebark pine was observed <10 m outside the GLORIA summit zone on the north aspect of Spring Mountain. A few small (<0.5 m tall) individuals occurred within and near the summit zone at Sheep Mountain South. In 2018, a few alive and dead whitebark pine seedlings were observed on Sheep Mountain. Persistence of those still alive seemed doubtful.

Plant identification was relatively straightforward for most species after we spent time reviewing the local flora before sampling each summit. Taxa that presented at least occasional identification problems included *Elymus scribneri* versus *Elymus elymoides* at Spring Mountain and Sheep Mountain. Both species were recorded, but for data entry consistency purposes, all *Elymus* were assigned to *Elymus scribneri* even though in some cases plants may have been *Elymus elymoides*. At one point there was confusion between *Packera werneriifolia* and *Senecio fremontii* at multiple summits. Closer inspection showed that only *Packera werneriifolia* occurred within the summit zones. The four species of *Minuartia* were occasionally problematic. In a few cases *Minuartia obtusiloba* may have been mistaken for another *Minuartia* species. *Poa* was the most problematic genus encountered. Questionable identifications were recorded as *Poa* sp. on data sheets. Each summit had a small number of taxa identified to the genus rank only due to the lack of reproductive structures or

other morphological features needed for confident identification. The 12 voucher specimens collected (Table 2) will be deposited in the Snake River Plains Herbarium at Boise State University. We did not collect vouchers for any species that appeared to be locally rare.

Programmed soil temperate data loggers were buried on north, south, east, and west aspects at Sheep Mountain South in 2019. In addition, we revisited buried soil temperature data loggers deployed in 2018 at Bruce Canyon Peak, Spring Mountain, and Sheep Mountain to make sure they were working properly and to download the first year of soil temperature data. Soil temperature profiles look relatively similar for each summit and aspect (Figure 4). The U-shaped temperature profiles show a steady decline from summer high to winter low and then a steady increase back towards summer highs. The exception was the east aspect on Spring Mountain. It had a constant temperature of approximately 0°C (32°F) from mid-November to late-May/early June, suggesting constant and sufficiently deep snow cover to keep the ground insulated. Profiles also show maximum summer soil temperature was highest on Bruce Canyon Peak (the lowest elevation summit) and lowest on Sheep Mountain (the highest elevation summit). In addition, maximum summer soil temperature were slightly lower on the north aspect compared to other aspects. The coldest winter temperatures occurred on west and north aspects for Bruce Canyon Peak and Spring Mountain, but on the east aspect for Sheep Mountain (no data logger deployed on the north aspect).

Bee community inventory

Flowers of forb species on the wind-swept GLORIA summits had little to no bee visitation on the days bee surveys were conducted. However, slopes below and saddles between the peaks did have bee activity where meadows were out of the wind. Bees were net-collected at flowers, trying to represent the prevalent bee species visiting each wildflower species. Bees of the genus *Osmia* prevailed in terms of species and individuals, followed by *Bombus* (bumblebees) and a smattering of other taxa (Appendix 5). All of the genera and most of the species are found at lower elevations in this region. Conversely, many taxa of lower elevations were missing, noticeably the otherwise ubiquitous and abundant family of sweat bees (Halictidae). Few taxonomic pollen specialists (oligoleges) were found, excepting *Osmia brevis*, a wide-ranging *Penstemon* specialist caught at *P. attenuatus*. Non-native bees, such as honeybees, were absent. Most bees species collected were ground-nesters, but for a few wood-nesters and a very few twig-nesters. Flowering individuals of the regional alpine endemic *Trifolium haydenii* were visited primarily by two species of ground-nesting *Osmia* bees, *O. tanneri* and *O. paradisica*. Both sought nectar and pollen. These two alpine/boreal bee species are rare in collections. Both probably have a 2-yr life cycle. These collections are the first pollinator records for this uncommon native clover.

DISCUSSION

The Idaho GLORIA team established and collected baseline data at four GLORIA summits in the Lemhi Mountains target region during the summers of 2018 and 2019. It is recommended that GLORIA summits be resampled at intervals of 5 to 10 years (Pauli et al. 2015). The main goals of the GLORIA program are to (1) accumulate a standardized, quantitative dataset on plant species richness, composition, and abundance, and for ground surface attributes; and on soil temperature and snow cover period in mountain systems world-wide; (2) quantify changes in species and vegetation patterns through long-term monitoring in permanent plots; (3) quantify changes in the abiotic environment such as the amount of unvegetated surface and the temperature regime; (4) build globally applicable and comparable indicators of climate change-driven impacts on alpine vegetation and biodiversity; (5) assess the risks of biodiversity losses and ecosystem instability due to climate change; and (6) provide information for developing conservation strategies and actions needed to mitigate climate-induced threats to biodiversity in alpine habitats (Pauli et al. 2015).

Alpine habitats in Idaho are confined to mountains in the central and east-central parts of the state. Several factors led to the selection of the central Lemhi Mountains for the first Idaho GLORIA target region: (1) a 2017 reconnaissance identified several summits in the Sheep Mountain and Spring

Mountain areas as potentially suitable for GLORIA; (2) previous alpine vegetation classification work in the Sheep Mountain area (Urbanczyzk and Henderson 1994) made available quantitative plant community and other basic floristic information that is lacking for most other alpine areas in Idaho; (3) presence of the Sheep Mountain RNA, a designation that recognizes the area's diverse alpine biota, confers extra land management protection, and encourages non-destructive research opportunities (Rust et al. 1996); (4) the presence of a few old mining roads that provide rough, but relatively ready access to the alpine, an uncommon advantage in a state where nearly all alpine areas are roadless; (5) exceptional support from the Caribou-Targhee and Salmon-Challis National Forests, the land managers for high elevation areas in the Lemhi Range.

An alpine plant community classification project in the Sheep Mountain area in the early 1990s provides one of the few alpine locations in Idaho with a quantitative plant community dataset (Urbanczyk and Henderson 1994). The classification identified eight alpine plant communities and described their apparent habitat preferences. Based on this classification, vegetation at the four GLORIA summits correspond to three different community types – the *Carex elynoides* community type at Bruce Canyon Peak; the *Calamagrostis purpurascens* – *Carex elynoides* community type at Spring Mountain; and the *Carex rupestris* community type at Sheep Mountain South and Sheep Mountain. In general, the classification found the *Carex elynoides* community type to occur in areas with a moderate slope, some snow accumulation, well-developed soil, and not directly exposed to winter winds. The *Calamagrostis purpurascens* – *Carex elynoides* community type occurs on sites that are more exposed and drier compared to the *Carex elynoides* type. The *Carex rupestris* community type occupies the highest, driest, most exposed sites that are likely blown snow-free in winter. These sites have shallow, rocky soil derived from dolomite and relatively sparse vegetation (Urbanczyk and Henderson 1994).

The high elevation vascular plant flora for the Sheep Mountain area is relatively well documented. Plant lists for the area are associated with the Sheep Mountain RNA establishment record (Rust et al. 1996), the Sheep Mountain alpine classification project (Urbanczyk and Henderson 1994), and a project that resampled a subset of the original alpine classification study plots (Mancuso and Lehman 2016). A comprehensive list based on these sources, plus the GLORIA data collected in 2018 and 2019 consists of 145 vascular plant species (Appendix 4) for the general Sheep Mountain area. Among the 84 plant species recorded during GLORIA sampling were 6 species not previously included in the earlier Sheep Mountain area lists, including *Allium* sp., *Arenaria kingii* var. *compacta*, *Cirsium scariosum*, *Cystopteris fragilis*, *Taraxacum* sp. (uncertain native species), and *Townsendia leptotes*.

A preliminary coarse-scale biogeographic overview for species recorded on the GLORIA summits reveals a wide range of elevational affinities, including 5% alpine (e.g., *Saxifraga oppositifolia* and *Townsendia condenstata*), 35% subalpine and alpine (e.g., *Draba lonchocarpa* and *Anemone multifida* var. *tetonensis*), 27% montane to alpine (e.g., *Frasera speciosa and Zigadenus elegans*), and 33% plains/foothills to alpine (e.g., *Stenotus acaulis* and *Eriogonum ovalifolium*). Most plant species recorded on the GLORIA summits are common and widespread. Based on rangewide distributions, approximately 3% are cosmopolitan (*Cystopteris fragilis* and *Taraxacum officinale*), 13% circumboreal (e.g., *Carex rupestris*, *Poa alpina*), 49% largely Rocky Mountain (e.g., *Phlox pulvinata* and *Ribes montigenum*), 24% widespread in western North America (e.g. *Calamagrostis purpurascens* and *Sedum lanceolatum*), 3% Pacific Northwest (*Ericameria suffruticosa*), 6% regional endemics (e.g., *Lesquerella carinata* and *Trifolium haydenii*), and 3% Idaho endemics (*Cymopterus douglassii* and *Draba oreibata*).

Two species of conservation concern were recorded during GLORIA sampling. *Cymopterus douglassii* is an east-central Idaho endemic known from a few populations in the Lost River Range and from a population in the Sheep Mountain area in the Lemhi Range (Idaho Natural Heritage Program 2019). It is a U.S. Forest Service Region 4 Sensitive plant species for both the Salmon-

Challis NF and the Caribou-Targhee NF. We found *Cymopterus douglassii* to be relatively common on both the Sheep Mountain South and Sheep Mountain GLORIA summits. Both summits lacked obvious, immediate threats to *Cymopterus douglassii* or its habitat. Whitebark pine is a federal Candidate species for listing under the Endangered Species Act (U.S. Fish and Wildlife Service 2011), and also a Sensitive species for the Salmon-Challis NF and the Caribou-Targhee NF. At the GLORIA summit zones, whitebark pine occurred as a single small individual tucked beneath a shelf of exposed bedrock at Spring Mountain; as a few scattered small individuals at Sheep Mountain South; and as a few alive and dead seedlings on Sheep Mountain. Stands of whitebark pine form the upper treeline downslope of each GLORIA summit. One possible response to climate change is the upslope migration of whitebark pine into currently unsuitable alpine areas. This could have important conservation implications regarding the long-term persistence of whitebark pine in the east-central Idaho mountains. GLORIA plots are now available to monitor, detect, and document this possibility in the Lemhi Range, especially with the placement of downslope survey transects for whitebark pine at the Bruce Canyon Peak and Spring Mountain sites. GLORIA monitoring information also has relevance to the conservation of other plant and animal species that use Idaho's alpine habitats. For example, Jim Cane (WildBeecolgy, Logan, UT) has conducted a bee community inventory in association with the GLORIA summits. Initiated in 2018 and continued in 2019, this effort produced an initial list of bee pollinators for the alpine zone in the Lemhi Mountains.

Sheep Mountain, Sheep Mountain South, and Bruce Canyon Peak are all located within the Sheep Mountain RNA, a designation that confers some protection and special management consideration. The objective of the Sheep Mountain RNA is to contribute to a national network of ecological areas dedicated to research, education, and maintenance of biological diversity by providing representation of alpine turf communities (Rust et al. 1996). The main management objective is to maintain the natural conditions and processes associated with the RNA in as near an undisturbed condition as possible without direct human impacts. The GLORIA project fits the type of research study encouraged by the RNA system. Establishing GLORIA in the Sheep Mountain area provides an opportunity for the RNA to serve as a regional reference for the study and long-term monitoring of ecological changes in an alpine ecosystem. Being part of the GLORIA program also positions Sheep Mountain RNA to be included in large-scale, worldwide analysis regarding climate change effects on alpine ecosystems.

High elevation ecosystems in Idaho are important for watershed, wildlife, biodiversity, aesthetic, and other values. Alpine habitats are predicted to be especially vulnerable to ecological changes related to climate change (Korner 2003, Gonzalez et al. 2010). GLORIA monitoring is relevant for Idaho because alpine habitat is relatively limited in distribution and extent in the state. Loss/contraction of alpine habitat due to climatic changes has the potential to seriously impact Idaho's high elevation biota. GLORIA monitoring information can provide land managers and others interested in high elevation ecosystems a better understanding of the relationships linking climate change and alpine biodiversity. GLORIA provides a program to help document, monitor, and assess possible long-term shifts and vulnerabilities to alpine vegetation in the Lemhi Range and other nearby mountains. This information has the potential to inform and help guide future conservation activities benefiting Idaho's mountain landscapes. As part of the GLORIA network, monitoring data from the Lemhi Range also has the potential to be viewed and evaluated in a larger context and contribute to efforts to better understand climate-related changes in alpine ecosystems at an international scale. Future conservation and mitigation efforts aimed at limiting biodiversity and habitat loss in alpine environments will benefit from this understanding.

The effort to establish a GLORIA monitoring program in Idaho has been a collaborative partnership involving the U.S. Forest Service – Region 4, Idaho State Office of the Bureau of Land Management, Boise State University, Idaho Natural Heritage Program at Idaho Department of Fish and Game, Idaho Fish and Wildlife Office of the U.S. Fish and Wildlife Service, and Mancuso Botanical Services. Plot maintenance and future resampling of GLORIA in the Lemhi Mountains target region will require

similar commitment, coordination, and collaboration efforts. Any possible expansion of GLORIA to additional target regions in Idaho will also depend on continued collaborative partnerships.

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Figure 1. Location of GLORIA in the Lemhi Mountains target region, Idaho.

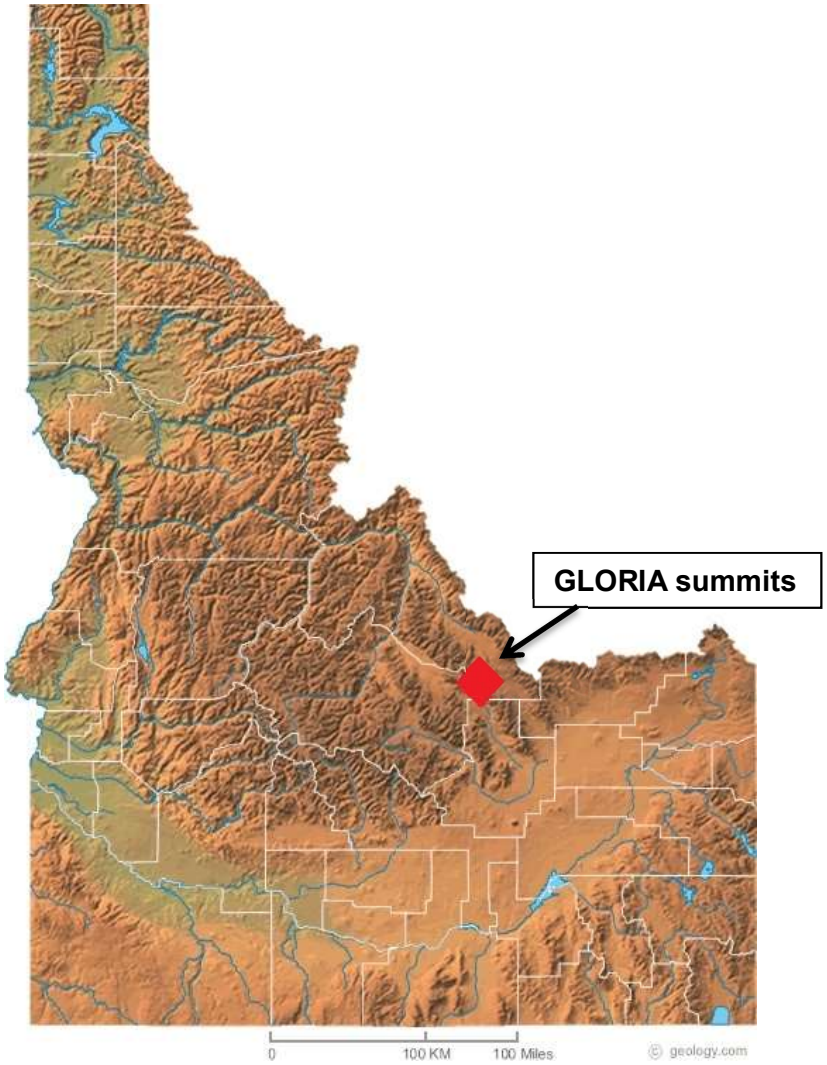

Figure 2. Map locations for GLORIA summits established in Lemhi Mountains.

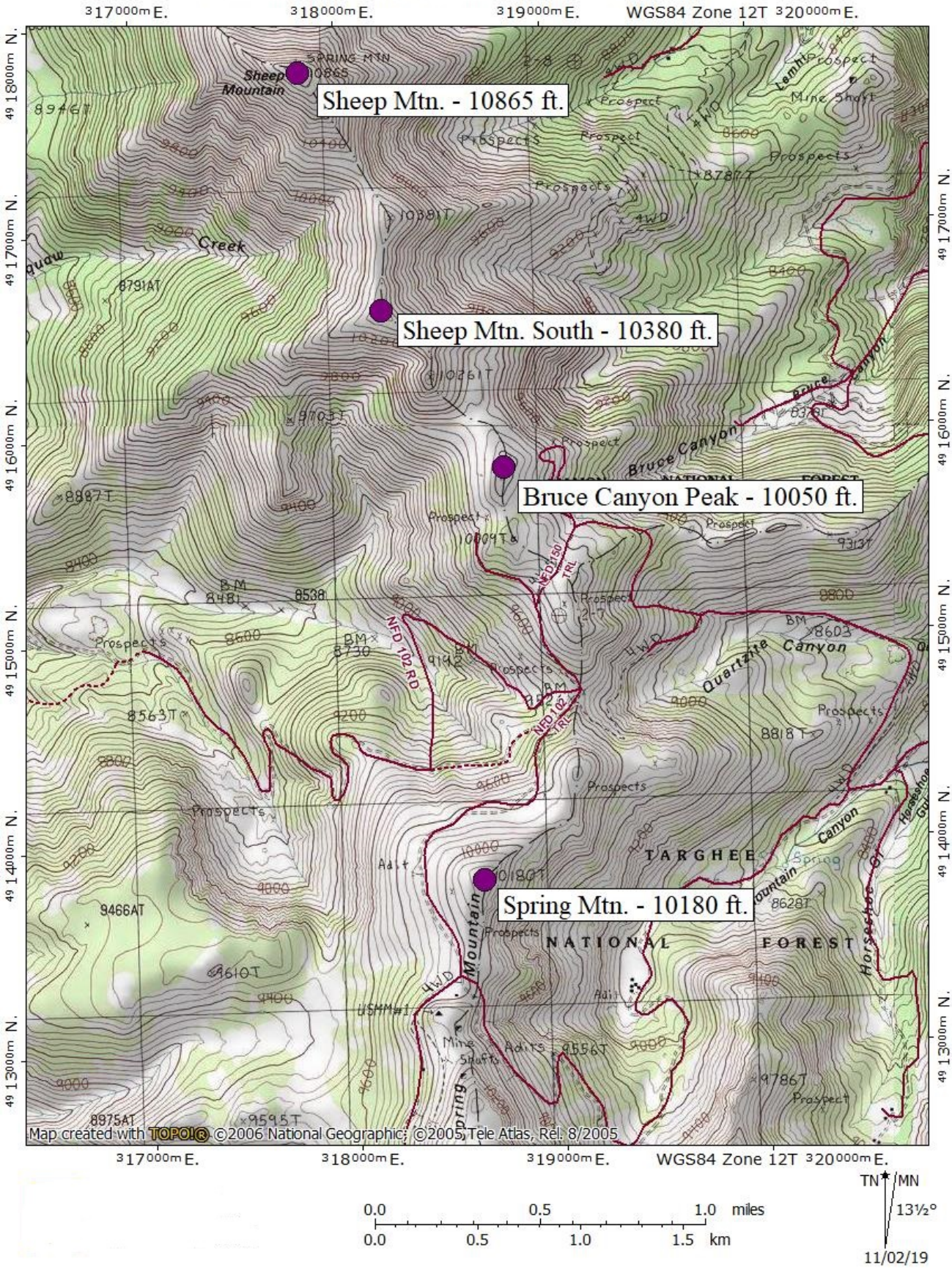

Figure 3. Stylized GLORIA summit with sampling design layout.
The layout shows that all sampling is conducted within the top 10 meters of the summit high point.

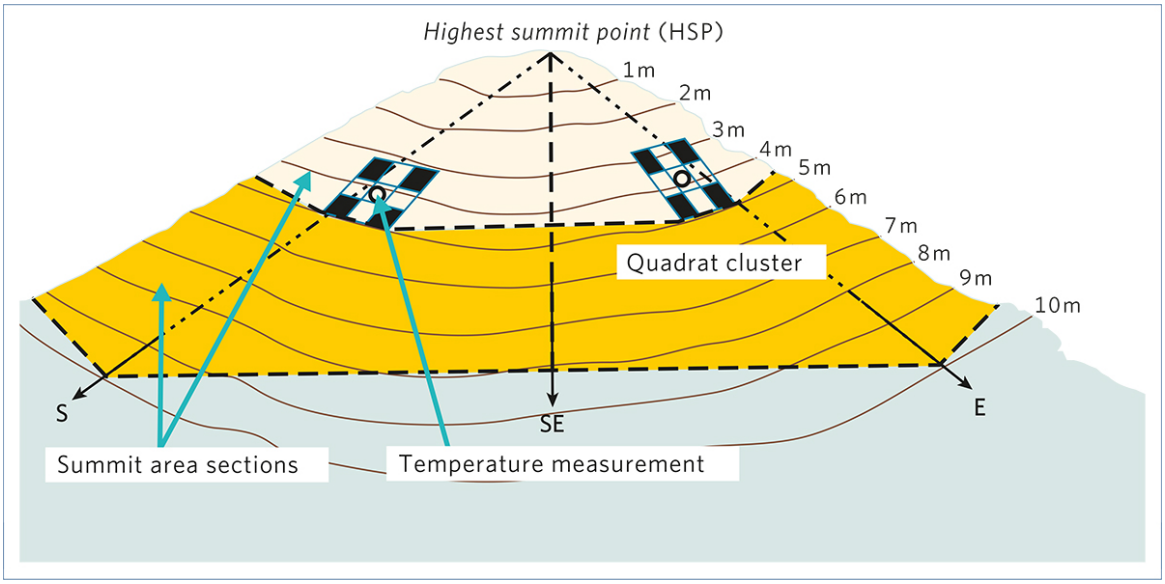

Figure 4. Soil temperature data logger profiles for three Idaho GLORIA summits, July 2018 to July 2019.

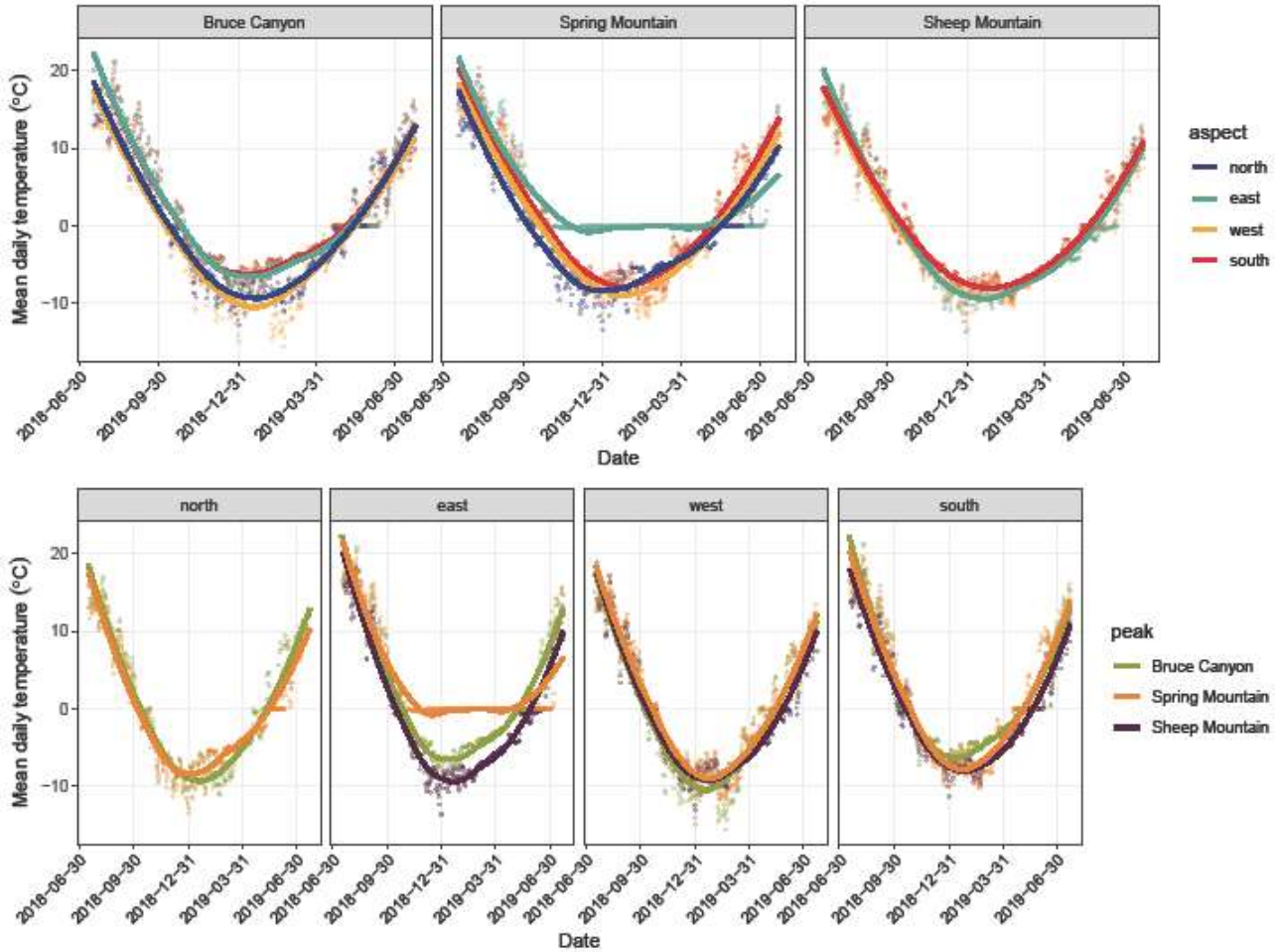

Table 2. Vascular plant species list for Idaho GLORIA summits.
Plant nomenclature follows the PLANTS database (Natural Resource Conservation Service 2019).
Common synonyms in parentheses. * = voucher specimen collected

Species Name	**Bruce Canyon Pk.**	**Spring Mtn.**	**Sheep Mtn. South**	**Sheep Mtn.**
Trees				
Pinus albicaulis		x	x	x
Shrubs				
Ericameria suffruticosa		x		
Ribes montigenum		x		
Forbs				
Achillea millefolium		x		
Agoseris glauca	x	x		
Allium sp.	x			
Anemone multifida	x	x		
Antennaria alpina *		x	x	
Antennaria lanata *	x	x		
Antennaria rosea	x	x		
Antennaria umbrinella	x	x	x	x
Arenaria congesta		x		
Arenaria kingii	x			
Astragalus australis	x			
Astragalus kentrophyta	x	x	x	x
Astragalus miser	x			
Arabis sp. (*Boechera* sp.)		x		
Bupleurum americanum		x		
Castilleja pallescens var. *inverta*	x	x	x	x
Cirsium scariosum		x		
Cymopterus douglassii *			x	x
Cymopterus nivalis	x	x	x	
Cystopteris fragilis		x		
Draba densifolia	x	x	x	x
Draba lonchocarpa var. *lonchocarpa*		x	x	x
Draba oligosperma	x	x	x	x
Draba oreibata var. *oreibata*			x?	x
Epilobium anagallidifolium (*Epilobium alpinum*)		x	x	
Erigeron compositus	x	x	x	x
Erigeron simplex		x		x
Erigeron radicatus *		x	x	
Eriogonum ovalifolium		x		
Eritrichium nanum var. *elongatum*	x	x	x	x
Frasera speciosa		x		
Heuchera grossulariifolia	x	x		

Species Name	Bruce Canyon Pk.	Spring Mtn.	Sheep Mtn. South	Sheep Mtn.
Ipomopsis congesta	x			
Ivesia gordonii			x	x
Lesquerella paysonii (*Physaria carinata*)		x		x
Linum lewisii	x	x		x
Lloydia serotina var. *serotina*	x	x	x	x
Minuartia austromontana (*Arenaria rossii*)		x	x	x
Minuartia nuttallii (*Arenaria nuttallii*)		x		
Minuartia obtusiloba * (*Arenaria obtusiloba*)	x	x	x	x
Minuartia rubella (*Arenaria rubella*)		x		
Oxytropis besseyi var. *argophylla*	x	x	x	x
Packera werneriifolia * (*Senecio werneriifolius*)	x		x	x
Pellaea breweri		x		
Penstemon attenuatus	x			
Penstemon humilis	x			
Phlox albomarginata			x	
Phlox multiflora	x	x	x	
Phlox pulvinata	x	x	x	x
Potentilla ovina	x	x	x	
Saxifraga oppositifolia		x	x	x
Sedum lanceolatum	x	x	x	
Selaginella densa	x			
Smelowskia calycina var. *americana*		x	x	x
Solidago multiradiata *	x	x	x	x
Stenotus acaulis	x	x	x	
Synthyris pinnatifida	x	x	x	
Taraxacum officinale		x	x	
Taraxacum sp. (native)			x	
Tetraneuris grandiflora (*Hymenoxys grandiflora*)	x	x	x	x
Townsendia condensata	x	x		
Townsendia leptotes		x		
Townsendia alpigena * (*Townsendia montana*)		x	x	
Townsendia parryi	x	x		
Trifolium haydenii		x		
Unknown sp.			x	
Valeriana acutiloba		x		
Zigadenus elegans		x	x	

Species Name	Bruce Canyon Pk.	Spring Mtn.	Sheep Mtn. South	Sheep Mtn.
Graminoids				
Calamagrostis purpurascens	x	x	x	x
Carex elynoides	x	x	x	x
Carex rupestris	x	x	x	x
Elymus elynoides *				x
Elymus scribneri (*Agropyron scribneri*)		x		x
Festuca idahoensis		x		x
Leucopoa kingii	x	x		
Poa alpina *		x	x	x
Poa fendleriana	x		x	
Poa glauca *	x			
Poa secunda *	x	x		x
Pseudoroegneria spicata (*Agropyron spicatum*)	x	x		
Trisetum spicatum		x		x

Table 3. Average percent cover value for 1m x 1m quadrat sampling on Idaho GLORIA summits.
N = north aspect, S = south aspect, E = east aspect, W = west aspect.
x = species not recorded in any 1m x 1m quadrats for that summit.

	Bruce Canyon Pk.					**Spring Mtn.**					**Sheep Mtn. South**					**Sheep Mtn.**			
Surface Features	**N**	**S**	**E**	**W**	**Avg.**	**N**	**S**	**E**	**W**	**Avg.**	**N**	**S**	**E**	**W**	**Avg.**	**S**	**E**	**W**	**Avg.**
Vascular plants	47.0	31.0	28.2	37.8	36.0	26.5	41.9	7.2	35.5	27.8	25.4	26.8	1.4	49.6	25.8	23.1	31.0	21.5	25.2
Solid rock	0	0.5	2.2	0.2	0.7	4.6	0.7	18.9	1.5	6.4	2.5	25.1	17.0	1.0	11.4	8.2	5.2	7.8	7.1
Scree	47.2	56.5	52.8	50.2	51.7	65.6	44.6	54.8	56.7	55.4	68.6	43.2	78.5	43.7	58.5	67.3	58.7	66.1	64
Lichens	1.4	1.2	0.2	0.5	0.8	0.3	1.2	0.02	1.5	0.8	2.1	1.5	0	2.2	1.5	0.1	2.5	0.8	1.1
Bryophytes	0.1	2.1	0.5	0.4	0.8	0.07	0.2	0	0.4	0.2	0	0.02	0	0.2	0.03	0.05	0.1	0.1	0.1
Bare ground	0.6	4.6	6.2	2.9	3.6	0.3	0.4	17	0.4	4.5	0.6	0.7	3.1	0.3	1.2	0.2	0.2	1.8	0.8
Litter	3.6	3.4	9.9	8.0	6.4	2.6	11.0	2.0	4.0	4.9	0.8	2.7	0	3.0	1.6	0.9	2.3	1.9	1.7
Forbs																			
Agoseris glauca	0	0.2	0	0	0.05	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Antennaria alpina	x	x	x	x	x	0	0	1	0	0.3	0	0	0.5	0	0.1	x	x	x	x
Antennaria rosea	0	0.2	0	0	0.04	0	0.5	0	0	0.1	x	x	x	x	x	x	x	x	x
Antennaria umbrinella	x	x	x	x	x	0.05	0	0	0.05	0.02	0	0.1	0	0	0.02	x	x	x	x
Antennaria sp.	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	0	0.02	0	0.01
Arenaria kingii	0	1.4	1.3	0	0.7	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Astragalus australis	0.9	0	0	0.7	0.4	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Astragalus kentrophyta	0.1	0	0	0	0.02	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Bupleurum americanum	x	x	x	x	x	0.07	1.4	0	3.0	1.1	x	x	x	x	x	x	x	x	x
Castilleja pallescens	0	0.2	0	0	0.03	0	0.1	0	0.02	0.03	0.2	0.2	0	0.5	0.2	0.2	0	0	0.06
Cymopterus douglassii	x	x	x	x	x	x	x	x	x	x	1.9	2.3	0	1.4	1.4	1.2	4.8	1.1	2.3
Cymopterus nivalis	0	3.9	4.0	0	1.9	0	0.07	0	0	0.02	x	x	x	x	x	x	x	x	x
Cystopteris fragilis	x	x	x	x	x	0	0	0.1	0	0.03	x	x	x	x	x	x	x	x	x
Draba densifolia	0.2	0.5	0.5	0	0.3	0.1	0.2	0	0	0.07	0.03	0.1	0	0.02	0.04	0.02	0	0	0.01
Draba oligosperma	0	0	0.1	0.1	0.06	0	0	0	0.3	0.07	0.03	0.05	0	0	0.02	x	x	x	x

	Bruce Canyon Pk.					Spring Mtn.					Sheep Mtn. South					Sheep Mtn.			
	N	**S**	**E**	**W**	**Avg.**	**N**	**S**	**E**	**W**	**Avg.**	**N**	**S**	**E**	**W**	**Avg.**	**S**	**E**	**W**	**Avg.**
Draba oriebata	x	x	x	x	x	x	x	x	x	x	0.07	0	0	0	0.02	x	x	x	x
Epilobium anagallidifolium	x	x	x	x	x	0	0	0.2	0	0.05	0	0	0.3	0	0.07	x	x	x	x
Erigeron compositus	0.02	0	0	0	0.01	0.02	2.6	0	0	0.6	0	0	0.03	0	0.008	x	x	x	x
Erigeron radicatus	x	x	x	x	x	x	x	x	x	x	0.07	0.05	0	0.05	0.04	x	x	x	x
Erigeron simplex	x	x	x	x	x	0	0	0	0.1	0.03	x	x	x	x	x	0	0.2	0	0.08
Eritrichium nanum	1.6	0.02	0.02	5.3	1.7	0.07	1.2	0	0.6	0.5	1.0	0.2	0	0.7	0.5	0.02	0	0	0.01
Frasera speciosa	x	x	x	x	x	0.7	0	0	0	0.2	x	x	x	x	x	x	x	x	x
Ipomopsis congesta	0.03	0	0	0.1	0.04	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Lesquerella carinata	x	x	x	x	x	0	0	0.05	0	0.01	x	x	x	x	x	x	x	x	x
Linum lewisii	x	x	x	x	x	0	0	0.1	0	0.02	x	x	x	x	x	x	x	x	x
Lloydia serotina	0.6	0	0	0.3	0.3	1.1	0	0	0.05	0.3	0	0	0.05	0	0.01	0.05	6.0	2.0	2.7
Minuartia austromontana	x	x	x	x	x	0.2	0	0	2.2	0.6	1.6	0.05	0	1.1	0.7	0.02	0.07	0.7	0.3
Minuartia nuttallii	x	x	x	x	x	0	0	0.2	0	0.04	x	x	x	x	x	x	x	x	x
Minuartia obtusiloba	**3.1**	0.3	0.9	3.6	2.0	1.9	0.7	0	1.5	1.0	1.5	1.1	0	0.5	0.8	1.0	0.1	0	0.4
Minuartia rubella	x	x	x	x	x	0	0.9	0	0	0.2	x	x	x	x	x	x	x	x	x
Oxytropis besseyi	1.5	0	0	1.3	0.7	0.7	2.9	0	2.6	1.4	2.1	0	0	0.3	0.6	x	x	x	x
Packera werneriifolia	0	0.05	0.05	0	0.02	0.02	0	0	0	0.01	0	0.1	0.1	0	0.05	0.3	0.1	0.1	0.2
Penstemon humilis	0	0.7	0	0	0.16	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Phlox multiflora	0	1.2	1.9	0	0.8	0.2	0	0	0	0.06	0	0	0.2	0	0.05	x	x	x	x
Phlox pulvinata	4.0	0	0	3.1	1.8	5	0.2	0	1.2	1.7	1.0	0.3	0	0.3	0.4	7.6	1.6	5.7	5.0
Potentilla ovina	1.1	1.8	5.2	0	2.1	0.7	0.6	0.2	0.6	0.5	0	0.3	0	0.1	0.1	x	x	x	x
Saxifraga oppositifolia	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	0	0	0.2	0.08
Sedum lanceolatum	0	0.05	0.02	0	0.01	x	x	x	x	x	0	0.07	0	0	0.02	x	x	x	x
Smelowskia calycina	x	x	x	x	x	0.05	0	0	0.2	0.06	0	0	0	0.1	0.03	0.3	0	0.9	0.4
Solidago multiradiata	x	x	x	x	x	0.3	0	2.6	0	0.7	0	0	0.03	0	0.008	0.02	0	0	0.01

	Bruce Canyon Pk.					Spring Mtn.					Sheep Mtn. South					Sheep Mtn.			
	N	**S**	**E**	**W**	**Avg.**	**N**	**S**	**E**	**W**	**Avg.**	**N**	**S**	**E**	**W**	**Avg.**	**S**	**E**	**W**	**Avg.**
Stenotus acaulis	0	1.1	0.3	0	0.4	0.1	0	0	0	0.03	x	x	x	x	x	x	x	x	x
Synthyris pinnatifida	0	0.2	0.2	0	0.1	0.1	0	0	0	0.03	0	0.5	0.07	0	0.1	x	x	x	x
Taraxacum sp. (native)	x	x	x	x	x	x	x	x	x	x	0	0	0.03	0	0.008	x	x	x	x
Tetraneuris grandiflora	0	0.9	0	0	0.2	0.7	1.1	0	0.6	0.6	0.3	0.8	0	0.4	0.4	0.2	0.1	0.05	0.1
Townsendia alpigena	x	x	x	x	x	x	x	x	x	x	0	0.07	0.03	0	0.02	x	x	x	x
Townsendia condensata	0	0	0	0.02	0.01	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Townsendia leptotes	x	x	x	x	x	0.1	0	0	0.05	0.04	x	x	x	x	x	x	x	x	x
Trifolium haydenii	x	x	x	x	x	2.0	0	0.2	0	0.6	x	x	x	x	x	x	x	x	x
Unknown sp.	x	x	x	x	x	x	x	x	x	x	0	0	0.03	0	0.008	x	x	x	x
Valeriana acutiloba	x	x	x	x	x	0	0	1.5	0	0.4	x	x	x	x	x	x	x	x	x
Graminoids																			
Calamagrostis purpurascens	5.5	0	0	0	1.4	2.0	25.5	0	11.7	9.8	1.0	2.8	0	15.0	4.7	x	x	x	x
Carex elynoides	19.5	10.8	7.0	18.2	13.9	6.5	4.8	0	9.0	5.1	0	2.6	0	6.8	2.3	x	x	x	x
Carex rupestris	12.3	5.8	0	0.5	4.6	4.2	7.0	0	3.2	3.4	15.2	16.4	0	26.0	14.4	14.8	19.2	11.3	15.1
Elymus scribneri	x	x	x	x	x	0	0	0.6	0	0.1	x	x	x	x	x	x	x	x	x
Leucopoa kingii	0	2.3	3.5	3.8	2.4	0.3	0	0	0	0.07	x	x	x	x	x	x	x	x	x
Poa alpina	x	x	x	x	x	x	x	x	x	x	0	0	0.03	0	0.008	x	x	x	x
Poa secunda	0	1.0	1.3	0.8	0.7	0.02	0	0	0	0.01	x	x	x	x	x	x	x	x	x
Poa sp.	x	x	x	x	x	0	0	0.02	0	0.01	0.03	0	0	0	0.008	0	0	0.1	0.04
Pseudoroegnaria spicata	0	1.0	3.0	0	1.0	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Trisetum spicatum	x	x	x	x	x	0	0	0.9	0	0.2	x	x	x	x	x	x	x	x	x

Table 4. Percent cover values for 10m x 10m square plot sampling on Idaho GLORIA summits.
N = north aspect, S = south aspect, E = east aspect, W = west aspect
North aspect not sampled for Sheep Mountain; East aspect not sampled for Sheep Mountain South
0 = species not recorded during line pointing sampling, but observed in the 10m x 10m plot (not done at Spring Mtn. west aspect).
x = species not recorded or observed in the 10m x 10m plot.

	Bruce Canyon Pk.					**Spring Mtn.**					**Sheep Mtn. South**				**Sheep Mtn.**			
Surface Types	**N**	**S**	**E**	**W**	**Avg.**	**N**	**S**	**E**	**W**	**Avg.**	**N**	**S**	**W**	**Avg.**	**S**	**E**	**W**	**Avg.**
Solid rock	1.0	1.9	3.7	0	1.6	6.1	0.7	12.0	7.1	6.4	6.8	7.5	4.2	6.2	28.4	5	15.6	16.3
Scree	35.9	39.5	33.7	32.6	35.4	55.3	39.8	67.0	49.5	52.8	38.2	41.8	31.1	37.0	52.2	64.8	57.2	58
Lichens	0	0.2	0	1.4	0.4	0	0.5	0	1.2	0.4	3.0	1.4	1.8	2.1	0.5	3.2	0.7	1.5
Bryophytes	0	0.5	0.2	0.2	0.2	0	0.2	0		0.06	0	0	0.2	0.06	0	0	0	0
Bare ground	2.7	5.8	12.3	3.6	6.1	4.6	0.7	11.8	1.0	4.5	2.5	0.2	0.2	1.0	1	0.2	0.5	0.5
Litter	15.1	7	6.3	6.7	8.8	2	4.1	0.2	6.8	3.3	0.2	0.5	0.2	0.3	1	3	0.7	1.5
Trees																		
Pinus albicaulis	x	x	x	x	x	x	x	x	x	x	x	0	0	0	x	x	x	x
Shrubs																		
Ribes montigenum	x	x	x	x	x	x	x	2.0	x	0.4	x	x	x	x	x	x	x	x
Forbs																		
Anemone multifida	x	x	x	x	x	x	x	0	x	0	x	x	x	x	x	x	x	x
Antennaria alpina	x	x	x	x	x	x	x	0	x	0	x	x	x	x	x	x	x	x
Antennaria rosea	0	0	0	x	0	x	x	x	x	x	x	x	x	x	x	x	x	x
Antennaria umbrinella	0	x	x	x	0	0	0.2	x	x	0.06	x	0	x	0	x	0	x	0
Arabis sp.	x	x	x	x	x	x	x	0	x	0	x	x	x	x	x	x	x	x
Arenaria kingii	x	1.7	3.7	x	1.3	x	x	x	x	x	x	x	x	x	x	x	x	x
Astragalus australis	0.5	x	x	0.5	0.2	x	x	x	x	x	x	x	x	x	x	x	x	x
Astragalus kentrophyta	0	x	x	x	0	x	x	x	x	x	x	x	x	x	0.2	x	x	0.08
Bupleurum americanum	x	x	x	x	x	0.2	1.4	0	2.7	1.1	x	x	x	x	x	x	x	x
Castilleja pallescens	x	0	0	x	0	0.2	0	0		0.06	0.5	0	0.5	0.3	0.5	x	x	0.1
Cirsium scariosum	x	x	x	x	x	x	x	0.5	x	0.1	x	x	x	x	x	x	x	x
Cymopterus douglassii	x	x	x	x	x	x	x	x	x	x	5.1	3.6	2.3	3.7	0.5	3.5	1.4	1.8
Cymopterus nivalis	0.2	5.3	8.0	0.2	3.4	x	0.2	0	x	0.06	x	x	x	x	x	x	x	x

	Bruce Canyon Pk.					Spring Mtn.					Sheep Mtn. South				Sheep Mtn.			
	N	**S**	**E**	**W**	**Avg.**	**N**	**S**	**E**	**W**	**Avg.**	**N**	**S**	**W**	**Avg.**	**S**	**E**	**W**	**Avg.**
Cystopteris fragilis	x	x	x	x	x	x	x	0.2	x	0.06	x	x	x	x	x	x	x	x
Draba densifolia	0.5	0.5	0.2	x	0.3	0.5	0.5	x	x	0.2	0.5	0	x	0.1	x	x	x	x
Draba lonchocarpa	x	x	x	x	x	x	x	x	x	x	x	x	x	x	0	x	x	0
Draba oligosperma	x	0	x	x	0	x	x	x	x	x	x	x	x	x	x	x	x	x
Draba oreibata	x	x	x	x	x	x	x	x	x	x	x	x	x	x	0	x	x	0
Epilobium anagallidifolium	x	x	x	x	x	x	x	0	x	0	x	x	x	x	x	x	x	x
Erigeron compositus	x	0	x	x	0	x	5.3	x	x	1.3	x	x	x	x	x	x	x	x
Erigeron radicatus	x	x	x	x	x	x	x	x	x	x	0	0	0	0	x	x	x	x
Erigeron simplex	x	x	x	x	x	0	x	x	x	0	x	x	x	x	x	0	x	0
Erigeron sp.	x	x	x	x	x	x	x	0	x	0	x	x	x	x	x	x	x	x
Eritrichium nanum	4.9	x	x	4.5	2.4	0	2.9	x	0.2	0.8	1.2	0.2	1.8	1.1	0	x	x	0
Frasera speciosa	x	x	x	x	x	0	x	x	x	0	x	x	x	x	x	x	x	x
Ipomopsis congesta	0	x	x	0	0	x	x	x	x	x	x	x	x	x	x	x	x	x
Ivesia gordonii	x	x	x	x	x	x	x	x	x	x	x	0	x	0	x	x	x	x
Lesquerella carinata	x	x	x	x	x	x	x	0	x	0	x	x	x	x	x	x	x	x
Linum lewisii	x	x	x	x	x	x	x	0.5	x	0.1	x	x	x	x	x	x	x	x
Lloydia serotina	0	x	x	0.7	0.2	1.5	x	x	x	0.3	x	0.2	x	0.07	0	2.4	2.9	1.8
Minuartia austromontana	x	x	x	x	x	0	x	x	x	0	0	0.2	1.3	0.5	0	x	0.2	0.08
Minuartia nuttallii	x	x	x	x	x	x	x	0	x	0	x	x	x	x	x	x	x	x
Minuartia obtusiloba	3.2	0.2	x	7.2	2.7	2.9	2.7	x	1.4	1.8	4.4	0.5	0.2	1.7	0	x	x	0
Minuartia rubella	x	x	x	x	x	x	x	x	1.4	0.3	x	x	x	x	x	x	x	x
Oxytropis besseyi	0.2	x	x	2.9	0.8	x	1.4	x	2.9	1.1	3.5	0.2	0.5	1.4	x	x	x	x
Packera werneriifolia	x	0	0.2	x	0.06	0	x	x	x	0	x	0.2	x	0.07	0	0	0	0
Penstemon humilis	x	0.2	0.2	x	0.1	x	x	x	x	x	x	x	x	x	x	x	x	x
Phlox multiflora	x	6.7	3.7	x	2.6	x	x	x	x	x	x	x	x	x	x	x	x	x
Phlox pulvinata	9.4	0.2	x	7.2	4.2	6.3	0.2	0	2.9	2.4	3.5	0.2	0.2	1.3	5.4	5.0	5.3	5.2
Potentilla ovina	0.5	1.9	3.7	0	1.5	0.2	1.5	0	1.7	0.8	0.5	0.2	x	0.2	x	x	x	x
Saxifraga oppositifolia	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	0	0.5	0.1

	Bruce Canyon Pk.					Spring Mtn.					Sheep Mtn. South				Sheep Mtn.			
	N	**S**	**E**	**W**	**Avg.**	**N**	**S**	**E**	**W**	**Avg.**	**N**	**S**	**W**	**Avg.**	**S**	**E**	**W**	**Avg.**
Sedum lanceolatum	x	x	0	x	0	0	x	x	x	0	x	0.2	x	0.07	x	x	x	x
Selaginella densa	0.5	x	x	x	0.1	x	x	x	x	x	x	x	x	x	x	x	x	x
Smelowskia calycina	x	x	x	x	x	0	x	x	x	0	x	x	x	x	0	x	0	0
Solidago multiradiata	x	x	x	x	x	0.5	x	1.5	x	0.5	x	x	x	x	x	x	x	x
Stenotus acaulis	x	2.1	1.2	x	0.8	0	0.2	0.5	x	0.1	x	x	x	x	x	x	x	x
Synthyris pinnatifida	x	x	x	x	x	2.9	x	x	x	0.7	x	x	x	x	x	x	x	x
Tetraneuris grandiflora	0.2	0.2	x	0.2	0.2	0.7	1.5	x	2.0	1.0	0.7	0.4	1.2	0.8	0.2	0.5	0.2	0.3
Townsendia alpigena	x	x	x	x	x	0	x	x	x	0	x	x	x	x	x	x	x	x
Townsendia condensata	x	x	x	0	0	x	x	x	x	x	x	x	x	x	x	x	x	x
Townsendia leptodes	x	x	x	x	x	0	x	x	0	0	x	x	x	x	x	x	x	x
Townsendia parryi	x	0	0	x	0	x	0	0.2	x	0.06	x	x	x	x	x	x	x	x
Trifolium haydenii	x	x	x	x	x	1.9	x	0	x	0.5	x	x	x	x	x	x	x	x
Valeriana acutiloba	x	x	x	x	x	x	x	1.0	x	0.2	x	x	x	x	x	x	x	x
Graminoids																		
Calamagrostis purpurascens	4.7	x	x	0.5	1.3	0.7	17.5	x	8.8	6.8	2.1	9.9	18.1	10.0	x	0.5	x	0.1
Carex elynoides	17.1	17.4	13.6	21.5	17.4	6.3	13.3	x	4.4	6.1	x	3.3	3.2	2.2	x	0	x	0
Carex rupestris	2.4	3.6	x	4.5	2.7	6.1	4.1	x	5.9	4.0	26.7	28.8	32.7	29.4	9.9	11.9	14.4	12.1
Elymus scribneri	x	x	x	x	x	x	x	2.5	x	0.6	x	x	x	x	x	x	x	x
Festuca idahoensis	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	0	0
Leucopoa kingii	0.5	2.9	4.5	5.0	3.3	0.5	0.5	x	x	0.2	x	x	x	x	x	x	x	x
Poa alpina	x	x	x	x	x	0	x	x	x	0	x	x	x	x	x	x	x	x
Poa fendleriana	0	0.2	x	0	0.06	x	x	x	x	x	0.5	x	x	0.1	x	x	x	x
Poa secunda	x	0.7	2.2	x	0.7	x	x	x	x	x	x	x	x	x	x	x	x	x
Poa sp.	0.2	x	x	0	0.06	0.2	0.2	x	x	0.1	x	x	x	x	x	x	x	x
Pseudoroegnaria spicata	x	0.7	2.0	x	0.6	x	x	x	x	x	x	x	x	x	x	x	x	x
Trisetum spicatum	x	x	x	x	x	x	x	0	x	0	x	x	x	x	x	x	x	x

Table 5. Plant species richness by aspect for the Idaho GLORIA summits.
Quadrats = # species recorded in 1mx1m square quadrats
10x10m = # species recorded in 10m x 10m plots
ns = not sampled

	Bruce Canyon Pk.		**Spring Mtn.**		**Sheep Mtn. South**		**Sheep Mtn.**	
	Quadrats	10x10m	Quadrats	10x10m	Quadrats	10x10m	Quadrats	10x10m
North	14	22	26	29	15	16	ns	ns
South	21	23	16	20	19	22	13	15
East	16	20	13	23	12	ns	10	13
West	13	17	19	20	16	16	10	11

Table 6. Plant species tally by abundance rank category for Summit Area Sections at Idaho GLORIA summits.
"5" refers to SAS plots in summit's upper 5 meter zone and "10" refers to the summit's 5-10 meter zone.
ns = not sampled

	Summit Area Section (SAS)							
	NE-SE 5	SE-SW 5	SW-NW 5	NW-NE 5	NE-SE 10	SE-SW 10	SW-NW 10	NW-NE 10
Bruce Canyon Pk.								
Very rare	8	8	4	6	7	3	6	9
Rare	8	6	5	4	13	12	4	7
Scattered	8	9	5	2	5	8	5	6
Common	3	6	4	5	4	5	6	3
# taxa	22	29	18	17	29	28	21	25
Spring Mtn.								
Very rare	14	18	8	9	16	11	2	7
Rare	7	8	6	14	7	22	10	17
Scattered	6	6	7	3	7	6	8	10
Common	7	8	4	4	1	9	8	7
# taxa	34	40	25	30	31	48	28	41
Sheep Mt. S								
Very rare	12	3	2	14	ns	8	5	ns
Rare	7	5	6	9	ns	3	4	ns
Scattered	9	8	5	8	ns	7	10	ns
Common	3	7	5	3	ns	7	4	ns
# taxa	31	23	18	34	ns	25	23	ns
Sheep Mtn.								
Very rare	6	11	3	1	6	6	4	ns
Rare	4	7	3	3	5	6	2	ns
Scattered	3	4	5	2	3	6	3	ns
Common	3	2	2	2	4	2	4	ns
# taxa	16	24	13	8	18	20	13	ns

Table 7. Summit Area Section vascular plant species summary for Idaho GLORIA summits. N = 8 SAS plots for Bruce Canyon Peak and Spring Mountain, N = 6 Sheep Mountain South, and N = 7 for Sheep Mountain.

	Bruce Canyon Pk.	**Spring Mtn.**
# of taxa recorded	45	70
# of taxa scored only "Very Rare" or "Rare"	26 (58%)	47 (67%)
Taxa recorded in all SAS plots	*Carex elynoides,* *Potentilla ovina*	*Bupleurum americanum* *Carex elynoides, Leucopoa kingii* *Potentilla ovina*
Taxa scored "Common" in at least half of SAS plots	*Carex elynoides* *Potentilla ovina*	*Calamagrostis purpurarecens* *Carex elynoides, Carex rupestris* *Minuartia obtusiloba* *Oxytropis besseyi, Phlox pulvinata* *Tetraneuris grandiflora*
	Sheep Mtn. South	**Sheep Mtn.**
# of taxa recorded	46	35
# of taxa scored only "Very Rare" or "Rare"	27 (59%)	24 (69%)
Taxa recorded in all SAS plots	*Calamagrostis purpurarecens* *Carex elynoides, Carex rupestris* *Castilleja pallescens* *Cymopterus douglassii* *Draba densifolia* *Erigeron radicatus* *Eritrichium nanum* *Minuartia austromontana* *Minuartia obtusiloba* *Oxytropis besseyi* *Tetraneuris grandiflora*	*Carex rupestris* *Cymopterus douglassii* *Lloydia serotina* *Packera werneriifolia* *Phlox pulvinata* *Saxifraga oppositifolia* *Smelowskia calycina*
Taxa scored "Common" in at least half of SAS plots	*Calamagrostis purpurarecens* *Carex rupestris* *Castilleja pallescens* *Minuartia obtusiloba*	*Carex rupestris* *Lloydia serotina* *Phlox pulvinata*

Table 8. Summit Area Section ground surface attributes summary for Idaho GLORIA summits. N = 8 SAS plots for Bruce Canyon Peak and Spring Mountain, N = 6 Sheep Mountain South, and N = 7 for Sheep Mountain.

Attribute	**Average % top cover**			
	Bruce Canyon Pk.	**Spring Mtn.**	**Sheep Mtn. South**	**Sheep Mtn.**
Vascular plant	40.8	44.4	29.2	18.3
Solid rock	0.9	7.2	17.5	14.6
Scree	48.8	41.3	43.3	60.0
Lichens	0.7	0.9	1.9	0.8
Bryophytes	0.5	0.9	0.03	0.5
Bare ground	3.5	2.7	2.6	2.2
Litter	4.8	2.6	5.5	3.6